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Pacific Orca Distribution Survey (PODS) conducted aboard the NOAA ship *McArthur II* in March-April 2009

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Introduction

In 2001 the Southern resident killer whale (SRKW) population was petitioned for listing under the Endangered Species Act (ESA). A series of workshops were held in 2003 and 2004 to identify data gaps and risk factors associated with the 20% decline this population experienced in the late 1990s. The primary data gap identified with this population was its winter distribution. Although the population has been identifiable since 1976, only 12 documented sightings in the winter in coastal waters existed in 2001, ranging from central California to the Queen Charlotte Islands, British Columbia. With the 2005 listing of the population under the ESA, Critical Habitat designation was required but in the initial designation none of the coastal U.S waters were included due to a paucity of sighting data. In order to obtain location data to improve the Critical Habitat designation, as well as obtain other information on behavior and prey selection, winter cruises to locate SRKWs have been conducted annually from 2004, except for the year 2005 (no sea days were allocated to this task in FY05). Here we report on the sighting and acoustic data collected for killer whales and other marine mammal species and seabirds, as well as describe the oceanographic data collected during the Pacific Ocean killer whale and cetaceans Distribution Survey, March-April 2009 (PODS 2009) conducted aboard the NOAA ship *McArthur II*.

Survey Objectives

The overall objective of this cruise was to locate southern resident killer whales (SRKWs) in order to better document their winter range as well as improve our understanding of their behavior and habitat use in these areas. In addition, other biological and oceanographic data were collected to better characterize their environment. Other objectives included photo-identification, behavioral observations, and acoustic study of sounds produced by other cetaceans in this area during the winter.

Study Area

The survey tracklines for the project included the waters of the continental shelf from northern Washington to central Oregon. This region is within the range of most of the documented sightings of SRKW during the late March-early April timeframe.

Itinerary

The cruise began on 23 March 2009 in Seattle, Washington and ended on 9 April 2009 in Seattle, Washington. A set of predetermined tracklines were established prior to the survey to cover the portion of the study area with the highest probability of encounter of SRKW based on previous sightings. In general, the ship was to initially follow the tracklines from the entrance to the Strait of Juan de Fuca south to the mouth of the Columbia River. If no southern resident killer whales were encountered the ship followed a set of tracklines south, potentially as far as central Oregon, depending on weather and whale detections. The ship would then return north repeating these tracklines. Tracklines were modified during the cruise due to weather or other considerations. In addition, modifications were made by transiting directly to areas where recently reported

sightings of killer whales were likely to be southern resident killer whales. The final ship track is shown in Figure 1.

Methods and Materials

Surveys were conducted for marine mammals and seabirds during this cruise. Two survey methods for marine mammals were used, visual and acoustic. In addition, oceanographic data were collected. Scientific Personnel that collected these data are listed in Table 1.

Visual Surveys

Marine Mammals

Line-transect survey methods were the primary visual survey method. This effort was consistent with Southwest Fisheries Science Center's approach for use in estimating abundance (Kinzey et al. 2001). The *McArthur II* traveled at 9-10 knots (through the water) along the designated trackline. A daily watch for marine mammals was maintained during daylight hours by scientific observers on the flying bridge (approximately 0700 to 1800), except when the ship was stopped to conduct other sampling operations, or when precluded by weather. A team of three observers searched with 25x150 binoculars, 7X binoculars, and unaided eye. The two outboard observers scanned from 10 degrees across the trackline to 90 degrees abeam with the 25X binoculars. The observers reported sighting angle using the azimuth incorporated into the binocular mount (this azimuth was calibrated to zero at the beginning of the cruise). The recorder monitored the entire 180 degree field of view with 7x 50 binoculars and unaided eye. Sighting conditions, watch effort, sightings, and other required information were entered into a computer, using the program WinCruz (written by R. Holland, SWFSC), hooked up to the ship's GPS (for course, speed and position information). Observers worked for 30 minutes at each of the three stations and rotated through the three positions for a total of 1.5 hours on the flying bridge, with an hour break between sets of rotations.

If weather (sea state, rain, or fog) precluded effective observations with the 25x binoculars, a two observer watch (designated off-effort) was manned on either the flying bridge or bridge with 7x50 binoculars or unaided eye. The observers scanned with unaided eye and 7x50 binoculars for marine mammals. Sighting conditions, watch effort, sightings, and other required information were also entered into a computer by observers, using the program WinCruz, hooked up to the ship's GPS (for course, speed and position information).

On sighting a marine mammal or other feature of biological interest, the marine mammal observer team on watch occasionally requested the vessel be maneuvered to approach the cetacean school or feature for investigation. During these occasions, the team went off-effort to allow the ship to approach the group of marine mammals and make estimates of group size. For killer whale sightings, behavioral state data were collected and photographs were taken. Weather permitting, a small boat was deployed for biopsy, behavioral data collection, photographic, satellite tag deployment and other operations for killer whales. Depending on the duration and end location of the encounter the trackline was generally re-intersected at the closet point.

Seabirds

Surveys of marine bird distribution were recorded by trained observers during daylight hours when ship speed exceeded 2.5 m/s (5 knots). Two observers were on watch at all times during survey effort. Observers went off-effort for meals and rest as necessary to avoid fatigue. Observations began at dawn each morning. A primary observer counted and identified all flying or sitting birds within a strip transect extending 300 m out from the bow to the beam of the ship (90° arc), while the second observer recorded data and helped with identification and sightings of birds close to the ship. During mild weather, observations were collected from the flying bridge (deck height = 12.6 m) on the side of the vessel with the best viewing conditions for each survey (e.g., no glare). In the event of precipitation exceeding a light drizzle, observations were collected from the bridge wing in the lee of the wind or from inside the bridge (deck height 10.3 m).

Binoculars (8x magnification) were used to aid in counting and species identification. Data were called out to the secondary observer who immediately entered them into a laptop computer running the "SeeBird" data acquisition program v 3.3.1 (Southwest Fisheries Science Center, La Jolla, CA). The computer was linked to GPS satellite data input so that each observation was associated with a latitude/longitude position and time stamp. Behavior of seabirds was noted and recorded (e.g. sitting, feeding, flying and flight direction, etc). Marine mammals, large aggregations of seabirds, fish, and rare species observed beyond the 300-m observation zone were also recorded, using the SeeBird software's capability to annotate distance outside of 300-m and the "comment" feature in the software.

Acoustic survey - Two different types of acoustic monitoring systems were available during the cruise, a dual towed array system and sonobuoys.

Towed Arrays - hydrophones

The towed array system consisted of 2 hydrophones arrays: a 2 element array (array A); and a 5 element array (array B). Array A consisted of 2 elements with 3.15 m spacing and approximately 330m of lead in cable. The 2 elements for array A had an effective (i.e. flat) frequency response of 100 Hz – 40 kHz. Array A was the primary array deployed (i.e. day and night) during normal survey mode. Array B consisted of 5 elements: two paired phones at either end with 3m spacing between each element in the pair, and a single hydrophone near the middle (330 m from the end pair and 130m from the first pair) for a total aperture of 660m (between the first and last pair). The last element of array B consisted of a broad-band, high-frequency element with a flat frequency response up to 200 kHz. Array B was intended to complement array A during nighttime encounters with resident killer whales in order to improve tracking capabilities. Each array was spooled on its own hydraulically powered winch for deployment and retrieval. Usually, array A was deployed at lengths of 200-300m from the fantail of the ship, depending on the bottom depth and other factors. Approximately 10 lbs of lead weight was attached to each array approximately 180m from the end of the array to sink it to a suitable depth. Array B was deployed with 200m of cable from the first pair of elements (for a total length of ~ 660m).

The deck cable was connected to the dry end of the array after deployment via a weather-proof electronic connector. The deck cable led from the winch into the dry-lab where the array power supply, signal conditioning, and signal processing, and signal recording system were located on the *McArthur II*. Array A was powered by two 12V DC batteries using a differential power (positive, negative & ground) configuration. Array B was powered by a 16V gel-cell.

Towed Arrays - Signal conditioning system

All array signals were passed through a multi-channel low pass filter (Alligator Filter Tech. model AAF-2) with a corner frequency set at 48 kHz. A programmable 2 channel band-pass filter (Krohn-Hite model 3362) was used to high pass filter both channels from array A as needed with the corner frequency set between 500 Hz and 4 kHz (default set at 200Hz). When both arrays were deployed, five channels of acoustic data were acquired consisting of the following configuration: Channels 1 & 2 were obtained from the 2 elements from array A, and channels 3, 4 & 5 from the last 3 (of the 5 total) elements from array B. A fixed K-H band-pass filter set from 100 Hz to 85kHz was used for the elements of Array B (channel 3-5) to high pass the signals from each channel. All channels were fed into a MOTU Traveler PC digital interface. The MOTU interface was used to digitize all five channels of array signals and then sent to ISHMAEL via a fire-wire cable. During normal monitoring, only channels 1 and 2 from array A were recorded to disk.

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Towed Arrays - Signal processing and recording system

One laptop (Dell Latitude D810, 2.14 GHz, 2 GB RAM, 80 GB HDD, "Laptop B") was dedicated for running ISHMAEL sound localization and digital recording software (developed by D. Mellinger, OSU-PMEL, Newport, OR). A second laptop (IBM Thinkpad) was dedicated to running Whaletrack II (developed by Glenn Gailey, TAMUG, TX). These two computers were connected via a network connection to an Ethernet router which was used to pass information from ISHMAEL to Whaletrack II.

ISHMAEL was used to record acoustic data and process calls for localization. Generally, data were sampled and recorded at 96 kHz for both arrays. Two-channels were recorded when array A was deployed and 5 channels (2 from array A, and 3 from array B) when both arrays were deployed. In some instances other sample rates and channels were recorded and were documented in Whaletrack II as well as the field note-book. Recordings were made continuously at 10 minute intervals with times with most start-times aligned on the hour and every ten minutes after the hour.

Animal vocalizations were manually selected in ISHMAEL for localization by 'windowing' the signal with a pointing device (e.g. a trackball or touchpad). Depending on localization method selected n ISHMAEL (phone-pair or crossed pair) either a left-right ambiguous bearing, an un-ambiguous bearing, or a location was estimated. All bearings and locations were estimated relative to the ship's location. When using both arrays, instantaneous estimates of locations were possible using the "crossed-pair" localization method in ISHMAEL. The bearing or location estimate and additional information were automatically passed to Whaletrack II via the network connection.

Whaletrack II was used to plot bearings and/or location estimates passed from ISHMAEL. Whaletrack II also acquired and plotted ship position via a serial GPS connection. Ship-track history, current heading and speed as well as an estimated position of the array were calculated and stored in an MS-Access database created by Whaletrack II. Information about effort, acoustic contacts and settings of acoustic equipment (e.g. gain and filter cutoffs) were also recorded in Whaletrack II.

Bearings plotted in Whaletrack II were used to estimate the animal's location. This technique involved sequentially plotting several bearings to the target while steadily moving past it.

Bearings and estimated locations of animal calls were saved in a Whaletrack II database file. This information was also passed on the to the flying bridge and cruise leader as needed.

All acoustic data collected during on-effort periods were digitally recorded to internal hard drives and backed up to external hard drives for all on effort periods that were monitored.

Sonobuoy System

Type AN/SSQ-57B USN sonobuoys (effective audio frequency response 10 Hz – 20 kHz) transmitting at various radio frequencies (164-167 MHz range) were deployed as conditions warranted. Sonobuoys are self-contained units that automatically power-up upon contact with water and transmit sounds via radio waves. All sonobuoys were set at 90m hydrophone deployment depths and 8 hour operating life (auto-scuttle setting). The sonobuoy radio signals were received by a mast mounted antennae connected to an ICOM IC-PCR1000 receiver that was controlled through a PC-based software interface. Acoustic signals from the receiver were recorded to a hard-drive using ISHMAEL and a NI 6062E DAQ card or the internal PC sound card.

Towed Arrays – Monitoring

The acoustics system personnel consisted of four bio-acousticians whose main duties were to deploy, operate and monitor the acoustics system and perform acoustic localizations of whales when detected. A constant – three hour rotation was maintained by the acoustics team day and night.

Array A was deployed at the beginning of the project and was retrieved only during periods of severe weather, when navigation conditions made towing the array unsafe (e.g. in shipping channels), or during CTD operations. Array B was deployed primarily at night, to facilitate tracking, and recovered in the morning. After the first two nights it was decided that only array A would be deployed to facilitate ship maneuvers. The array(s) were retrieved during nighttime CTD operations (usually between 20:00 and 21:00) but were re-deployed immediately afterwards. Only 2 channel recordings were made from Array A, even when both arrays were deployed. This allowed faster computational times when obtaining bearings and localizations and saved storage space on the hard drives.

If killer whale sounds were detected at night, the bio-acoustician on watch would attempt to localize and track them until the visual observers came on watch at daybreak.

If southern resident killer whales were detected, every effort was made to remain with these animals for as long as possible. Visual sightings as well as acoustic data from the towed acoustic array or sonobouys were used to track the whales. Behavioral data were collected during visual observations, and if weather permitted, a small boat was deployed in order collect behavioral data, predation event remains, and photographs.

Photo-ID Photographs of marine mammals were taken on an opportunistic basis. The animals were either approached by the research vessel during normal survey operations, approached the research vessel on their own, or were approached by a small boat. Photographs of individuals were taken with digital 35 mm SLR cameras using 300 and 400 mm lenses for those species that have photo-ID existing catalogs.

Biopsy Sampling - Biopsies for genetic analyses of killer whales were collected on an opportunistic basis in U.S. and Canadian waters. Samples collected for killer whales were only taken from small boats using the method outlined by Barrett-Leonard et al. (1996). For cetaceans that approached within 10m to 30m of the bow of the *McArthurII* biopsy samples were collected using a dart fired from a dart rifle.

Prey remains/fecal collection – Prey remains from predation events (scales, tissue) of marine mammals and fecal samples were collected on an opportunistic basis. These samples were collected from animals that were approached by the small boat using a long-handled (4-m) fine-mesh net.

Behavioral Observations – Behavioral observations of marine mammals were taken on an opportunistic basis. The animals to be observed were approached by the research vessel during normal survey operations, approached the vessel on their own, or were approached by a small boat. Observations recorded from the *McArthurII* included general behavioral state. During small boat operations a focal follow approach was used that was similar to Ford and Ellis (2006).

Satellite tagging – Remotely deployed dorsal fin attached dart tags with a satellite-linked transmitter were deployed opportunistically during small boat operations with transient killer whales.

Oceanography

Thermosalinograph Sampling

The ship's Sea-bird Electronics Thermosalinograph (TSG) sampled surface water temperature and salinity continuously during the entire cruise track. The data from the TSG and from a GPS were continuously recorded by the ship's Scientific Computing System (SCS). The TSG information was also used in the field by the oceanographer to record latitude, longitude, surface water temperature, and salinity during expendable bathyothermograph (XBT) casts, surface water sampling, and CTD casts.

Expendable Bathyothermographs (XBTs) Deployment and Surface Water sampling

Expendable bathyothermographs (XBTs) were deployed at 0900, 1200, and 1500 hours, and surface water samples were collected at 0600, 0900, 1200, 1500, and 1800 hours local ship time, and at other times, under the discretion of the Chief Scientist (e.g., surface water samples are also taken every hour when in the presence of killer whales). For XBT deployments, Sippican Deep Blue probes were used and data were transmitted to the Shipboard Environmental data Acquisition System. After each XBT drop, a surface water sample for chlorophyll a analysis was collected in a bucket deployed over the side of the ship. Immediately following bucket sampling, a 50 ml sample of the water was filtered onto a 2.5 cm GF/F filter. All filters were stored frozen in labeled culture tubes until sample analysis, which took place at the Northwest Fisheries Science Center in Seattle, WA within one month following the completion of the cruise. For extraction, the filters were placed in culture tubes with 8 ml of 90% (v/v) acetone and stored in the freezer for a minimum of 2 hours. The tubes were then allowed to equilibrate with room temperature, and fluorescence was measured using a Turner Designs 10-AU Digital Field Fluorometer.

CTD Casts

A CTD (conductivity-temperature-depth) station was occupied each evening one hour after sunset, weather and sufficient depth permitting. In the event that a CTD cast was cancelled due to inclement weather or because the ship was tracking killer whales, an XBT was also deployed when the surface water sample was collected at 1800 hours. CTD data and seawater samples were collected using a SeaBird 9/11+ CTD with a 12-place rosette and Niskin bottles. All casts were to 1000m (depth permitting) with the descent rate set at 30 m/min for the first 100m of the cast, then 60 m/min after that, including the upcast between bottles. Niskin bottle water samples were collected at 12 standard depths (0, 10, 20, 30, 40, 50, 75, 100, 150, 200, 500, 1000) between the surface and 1000 meters, or to within 10 m of the bottom. For each cast, water samples were collected for chlorophyll a analysis at all depths to 200 m. Immediately following sampling, a 50 ml sample of the water was filtered onto a 2.5 cm GF/F filter. All filters were wrapped in foil, labeled, and stored frozen in Ziploc freezer bags until sample analysis, which occurred on the ship within <1-2 weeks of collection. Chlorophyll a extraction and analysis were conducted using the same protocol as above. Water samples for salinity analysis were collected at 100, 500, and 1000 m (or to within 10 m of bottom). Three additional salt samples were collected every other day so that the depths sampled were 30 m, 100m, 150m, 200 m, 500 m, and 1000 m. Water samples for salinity analysis were stored upright at ambient room temperature. Salinity samples were processed within one month after the cruise at the University of Washington Marine Chemistry Laboratory in Seattle. Water samples (approximately 40 ml) for nutrient analysis from each of the 11 depths up to 500 m were transferred into pre-rinsed (10% HCl and H2O) vials and frozen upright. Nutrient samples were processed within 6 months following the completion of the cruise, at the University of Washington Marine Chemistry Laboratory in Seattle.

Zooplankton and Ichthyoplankton Studies

Net tows for zooplankton and ichthyoplankton analysis were collected at night following the CTD. A 60cm diameter bongo net was used, towed to within 5m of the bottom or to depths no greater than 100m. 55 samples were collected, preserved in 5% formalin, and taken back to shore to be enumerated. The non-preserved side of the paired net system was immediately studied after each tow. Tows in which gravid euphausiids were present were saved. Egg production studies were done using up to 14 individuals from each of the two dominant euphausiid species *Euphausia pacifica* and *Thysanoessa spinifera*. As per protocol on the PICES website http://www.pices.int/projects/Euphasiid/PICES/Protocols/COMPLETE.pdf
During each bongo cast, a surface water sample for chlorophyll a analysis and nutrients was collected in a bucket deployed over the side of the ship. Immediately following bucket sampling, a 100 mL sample of the water was filtered onto a 2.5 cm GF/F filter. All filters were stored in a 15 mL centrifuge tube, labeled, and stored in the freezer for the duration of the trip. Chlorophyll a extraction was done at the Newport, OR research station. For extraction, 8 mL of 90% (v/v) acetone was added and stored in the freezer for a minimum of 24 hours. The tubes were then allowed to equilibrate to room temperature, and fluorescence was measured using a Turner Designs 10-AU Digital Fluorometer. Nutrient analysis; 30 mL from each surface bucket sample was frozen upright and brought back to Oregon State University Chemistry Laboratory in Corvallis for analysis. Chlorophyll a analysis and nutrient samples were processed within three months of the cruise.

Results and Discussion

Search Effort and Sightings – Marine mammals

A total of 2084.0 km were surveyed in the study area during 11.5 of the 18 total sea days, yielding an average of 181.2 km/day (Table 2, Figure 2). However, only 979.6 km were considered on-effort, and of the 1104.4 km total off–effort, 381.1 km were conducted on the flying bridge and 723.3 were conducted on the bridge. Survey efforts were hampered on 23 March and from 1-3 April due to inclement weather.

A total of 76 marine mammal sightings were made during all effort categories (Table 3). The majority of sightings were made while on-effort (58) although a few were observed while off–effort (18) (Table 4). Six identifiable cetacean species were sighted (Figure 3). The most commonly sighted species were gray whales (*Eschrichtius robustus*), followed by harbor porpoise (*Phocoena phocoena*) and.unidentified large whales. Seven of the nine groups of killer whales detected (two resident pods and seven transients) were initially sighted without an acoustic cue (see Acoustics section). No ship-based biopsy attempts were made.

Search effort and sightings - Seabirds

A total of 1,687.2 kilometers of on-effort survey observations were collected between 24 Mar 2009 and 8 April 2009; total effort for each day is shown in Table 5. The ship track covered by daytime, on-effort marine bird surveys is shown in Figure 4. Observation conditions were generally good: average Beaufort sea state was 4, and the Observing Condition factor, which is a qualitative measure of the ability to detect small, fast-moving species such as phalaropes or storm-petrels, was either Fair or Good for all surveys.

A total of 13,355 seabirds were observed and counted during on-effort transects within the 300 meter strip transect (Table 6). Eighty-nine percent of all birds counted comprised six species: common murre (*Uria aalge*, 46.5%), unidentified dark and sooty shearwater (*Puffinus griseus*, 26.8%), rhinoceros auklet (*Cerorhinca monocerata*, 7.0%), black-legged kittiwake (*Rissa tridactyla*, 5.8%), and Cassin's auklet (*Ptychoramphus aleuticus*, 3.1%). The observed species composition indicates an assemblage of resident breeding species (e.g. murres, rhinocerous auklets, gulls), increasing numbers of non-breeding early summer migrants (e.g. sooty shearwaters) and non-breeding late winter migrants (e.g. kittiwakes, fulmars). Additionally, small numbers of pink-footed shearwaters (*Puffinus creatopus*), Canada goose (*Branta canadensis*), a horned puffin (*Fratercula corniculata*), and a peregrine falcon (*Falco peregrinus*) were observed either off effort or outside of the 300 meter strip transect.

These seabird data continues to be analyzed and used for various projects addressing ecosystem dynamics and food web structure of the Northern California Current Large Marine Ecosystem.

Acoustic effort and detections

Acoustic monitoring was conducted around the clock when operations allowed. Array A was deployed for a total of 292 hours and Array A + B was deployed (dual arrays) for just over 21 hours. This resulted in a total deployment time for all array configurations of approximately 313 hours during the cruise for a total distance sampled of 4260 km (Figure 5). There were no significant malfunctions of the acoustic array or any related acoustic hardware.

Excluding the first and last days (when partial days only were possible) and the 1st – 3rd of April (when severe weather necessitated a port call) average daily acoustic effort (day and night) was approximately 21.1 hours per day. This represents 88% of the total survey time at sea. If the times the array had to be retrieved for the daily CTD cast and inclement weather periods (i.e. when the track-line was broken for transit to and from port) are excluded (~ 28.2 hrs) , the resulting 341.2 hrs of effort represents approximately 96.1% of the time 'available' for conducting acoustic effort.

During the acoustic array monitoring effort, six sonobuoys were also deployed. Five of these functioned correctly and successful recordings of killer whale vocalizations were made from four of these. Slight modifications to the receiver set up were made for the 4th and 6th (the 5th buoy did not function) sonobuoy deployments. Successfully functioning sonobuoys typically lasted 15-30 min after which the battery died and/or the sonobuoy was out of range.

A total of 11 acouctic detections of marine mammals were made, ten of which were attributed (or possibly attributed) to killer whales (Table 7). Of these, seven acoustic detections were visually confirmed, including two night-time detections of transient killer whales that were acoustically tracked until daylight. Of those detections not visually confirmed, two (# 7 and 8) consisted of a few faint killer whale calls, and the recording bouts were not of sufficient duration or quality to confirm the type or identity of the animals. The other acoustic detections (#1 and 9) were based on clicks and/or whistles and could not be positively attributed to killer whales. Upon further review, it may be possible to determine the ecotype of the animals in the detections; particularly, for detections 7 and 8 because the duration of the detection may be long enough to contain specific, identifiable calls.

Killer whale encounters

Two of the three ecotype of killer whales found in the North Pacific Ocean, transients and residents, were encountered during the cruise (Table 8). For the resident type, L pod from the southern community was observed on two separate occasions. We were able to conduct small boat operations with this group of whales for several hours. We collected two predation event samples from L pod on 26 March and one biopsy sample from southern resident killer whale (L12). The two predation event samples were identified as Chinook salmon, one from the Upper Columbia Summer/Fall Run and the other from Snake R. Spring/Summer Run.
Seven groups of transient killer whales were encountered off Washington and Oregon. Two biopsy samples were collected and 3 satellite tags were deployed.

Oceanography

Thirty four XBT drops, six CTD deployments, and 55 bongo net casts were made during the cruise (Tables 9, 10, 11, 12 and Figure 6). 84 daily surface chlorophyll samples, 58 CTD chlorophyll samples, 25 CTD salinity samples, 62 CTD nutrient samples, 48 bongo net associated surface chlorophyll samples, and 36 bongo net associated surface nutrient samples were collected.

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Table 1. Participating scientists.

Name	Position	Org
Brad Hanson	Chief Scientist, Acoustician	NWFSC
Dawn Noren	Co-Cruise Leader, Mammal Observer	NWFSC
Candice Emmons	Killer whale ID Specialist	NWFSC
David Ellifrit	Mammal Observer	Biowaves
Allan Ligon	Mammal Observer	Biowaves
Amy Kennedy	Mammal Observer	AFSC/NMML
Marla Holt	Acoustician	NWFSC
Aly Azarra	Acoustician	Biowaves
Nicole Nichols	Acoustician	NWFSC
Elizabeth Phillips	Seabird Observer	OSU/NWFSC
Terry Hunfield	Seabird Observer	NWFSC
Ryan Merrill	Seabird Observer	NWFSC
Jennifer Menkel	Oceanographer	NWFSC
Toby Auth	Oceanographer	NWFSC

Table 2. Visual survey effort summary for marine mammals (kilometers) by sea state.

Effort type	Sea State								
	0	1	2	3	4	5	6	7	Total
On Effort Flying Bridge	0	46.3	87.1	308.7	280.4	176.3	46.9	33.9	979.6
Off Effort Flying bridge	0	21.8	72.5	224.4	42.8	5.9	0.6	13.0	381.1
Off Effort Bridge	0	0	31.4	210.4	184.8	106.7	45.0	145.0	723.3
Total	0	68.1	191.0	743.5	508.0	288.9	92.5	191.9	2084.0

Table 3. Visual sightings summary - Cetaceans.

Code	Species	Total Sightings	Average group size
37	*Orcinus orca*	9	16.9
40	*Phocoena phocoena*	18	1.6
44	*Phocoenoides dalli*	6	5
69	*Eschrichtius robustus*	20	1.85
70	*Balenoptera spp.*	1	1
76	*Megaptera novaeangliae*	8	1.5
98	Unidentified Whale	1	2
79	Unidentified Large Whale	12	1.33
477	Unidentified Porpoise	1	1
	Total	76	

Table 4. Cetacean sightings.

Sighting #	Date	Time	Latitude	Longitude	Species code	Species	# of animals	Effort
1	24-Mar	8:20	48.3673	-125.0473	69	Er	3	On
2	24-Mar	12:11	47.988	-125.7021	98	Unid whale	2	On
3	24-Mar	15:04	48.0625	-125.04	44	Pd	7	On
4	24-Mar	19:03	47.8453	-125.359	44	Pd	5	On
5	25-Mar	7:58	47.593	-124.6106	69	Er	1	On
6	25-Mar	11:16	47.35	-124.607	79	Unid lg whale	1	On
7	25-Mar	11:58	47.3208	-124.4675	40	Pp	1	On
8	25-Mar	12:00	47.3176	-124.454	69	Er	1	On
9	25-Mar	12:03	47.3148	-124.4421	69	Er	3	On
10	25-Mar	12:09	47.3091	-124.4191	69	Er	1	On
11	25-Mar	12:12	47.3066	-124.4081	69	Er	1	On
12	25-Mar	17:35	47.1101	-124.3931	79	Unid lg whale	1	On
13	26-Mar	9:17	47.0116	-124.5126	37	Oo	38	Off
14	27-Mar	7:45	46.3002	-124.3749	69	Er	5	On
15	27-Mar	13:37	46.2451	-124.2448	40	Pp	1	On
16	27-Mar	13:48	46.263	-124.2283	37	Oo	38	On
17	28-Mar	8:33	47.2371	-124.5658	37	Oo	30	Off
18	28-Mar	17:41	48.067	-124.8925	69	Er	2	Off
19	29-Mar	15:06	48.2611	-123.4218	37	Oo	10	Off
20	30-Mar	9:40	48.3641	-125.6025	79	Unid lg whale	2	Off
21	30-Mar	9:45	48.3676	-125.607	79	Unid lg whale	1	Off
22	30-Mar	9:58	48.3761	-125.6176	76	Mn	2	Off
23	30-Mar	10:18	48.3911	-125.6343	76	Mn	1	Off
24	30-Mar	10:21	48.3913	-125.6368	76	Mn	1	Off
25	30-Mar	11:06	48.406	-125.69	76	Mn	2	On
26	30-Mar	15:06	48.3606	-125.2451	69	Er	1	Off
27	30-Mar	18:49	48.1781	-125.3038	40	Pp	1	Off
28	31-Mar	14:41	47.5326	-125.0471	37	Oo	6	Off
29	1-Apr	18:21	48.2801	-123.4473	40	Pp	2	Off
30	4-Apr	8:36	48.3945	-124.9753	79	Unid lg whale	1	On
31	4-Apr	8:52	48.3671	-125.0248	69	Er	2	On
32	4-Apr	10:00	48.2496	-125.2351	79	Unid lg whale	2	On
33	4-Apr	11:17	48.1343	-125.4401	79	Unid lg whale	1	On
34	4-Apr	14:42	48.0343	-125.2761	76	Mn	2	On
35	4-Apr	14:47	48.0368	-125.2561	76	Mn	2	On
36	4-Apr	15:00	48.0428	-125.2073	76	Mn	1	On
37	4-Apr	15:47	48.0713	-125.0126	40	Pp	1	On
38	4-Apr	15:53	48.0668	-124.998	40	Pp	3	On
39	4-Apr	15:55	48.0676	-124.9898	40	Pp	1	On
40	4-Apr	15:56	48.068	-124.9818	40	Pp	2	On
41	4-Apr	15:58	48.0683	-124.9818	40	Pp	1	On
42	4-Apr	16:10	48.0728	-124.9355	40	Pp	3	On
43	4-Apr	16:19	48.0775	-124.899	79	Unid lg whale	1	On
44	4-Apr	16:35	48.0861	-124.8343	79	Unid lg whale	2	On

Sighting #	Date	Time	Latitude	Longitude	Species code	Species	# of animals	Effort
45	4-Apr	16:58	48.04	-124.8636	69	Er	1	On
46	4-Apr	17:24	47.9971	-124.9083	79	Unid lg whale	1	On
47	4-Apr	18:13	47.9175	-125.001	37	Oo	5	On
48	4-Apr	18:27	47.9106	-125.048	40	Pp	1	Off
49	5-Apr	10:02	46.8178	-124.326	69	Er	2	On
50	5-Apr	10:38	46.719	-124.358	69	Er	1	On
51	5-Apr	12:46	46.5008	-124.6221	76	Mn	1	On
52	5-Apr	14:33	46.3568	-124.2473	69	Er	2	On
53	5-Apr	14:36	46.3521	-124.2355	69	Er	2	On
54	5-Apr	14:51	46.3306	-124.2236	40	Pp	2	On
55	5-Apr	14:53	46.3271	-124.2316	69	Er	1	On
56	5-Apr	14:55	46.3241	-124.2381	69	Er	2	On
57	5-Apr	15:04	46.3113	-124.2826	40	Pp	1	On
58	5-Apr	15:12	46.2966	-124.2951	40	Pp	1	On
59	5-Apr	15:46	46.2436	-124.3995	37	Oo	4	On
60	6-Apr	6:54	45.8085	-124.5576	37	Oo	15	Off
61	6-Apr	12:05	45.8516	-124.3508	40	Pp	3	On
62	6-Apr	12:14	45.8428	-124.3178	40	Pp	2	On
63	6-Apr	13:18	45.7471	-124.1641	40	Pp	1	On
64	6-Apr	14:29	45.5453	-124.2163	40	Pp	2	On
65	6-Apr	17:14	45.0535	-124.216	477	Unid porpoise	1	On
66	6-Apr	17:52	44.9405	-124.2368	79	Unid lg whale	1	On
67	6-Apr	18:35	44.8636	-124.364	44	Pd	2	On
68	6-Apr	18:52	44.8401	-124.4205	44	Pd	1	On
69	6-Apr	18:54	44.8373	-124.4275	44	Pd	10	On
70	6-Apr	19:18	44.8043	-124.5101	70	Balenoptera sp	1	On
71	7-Apr	9:56	44.6456	-124.1916	79	Unid lg whale	2	On
72	8-Apr	9:16	47.2388	-124.6025	44	Pd	5	On
73	8-Apr	10:33	47.4256	-124.676	37	Oo	6	On
74	8-Apr	18:27	48.1788	-124.8816	69	Er	4	Off
75	8-Apr	18:37	48.204	-124.881	69	Er	1	Off
76	8-Apr	18:56	48.254	-124.8875	69	Er	1	Off

Table 5. Marine bird survey effort, in linear distance surveyed by day.

Survey Date	Total kilometers surveyed
24/Mar/09	172.4
25/Mar/09	186.0
26/Mar/09	24.1
27/Mar/09	97.0
28/Mar/09	65.8
29/Mar/09	73.9
30/Mar/09	94.4
31/Mar/09	100.5
1/Apr/09	131.4
2/Apr/09	56.1
4/Apr/09	162.9
5/Apr/09	139.7
6/Apr/09	104.6
7/Apr/09	120.0
8/Apr/09	158.2
Total	1687.2

Table 6. Seabird species observed during marine bird survey effort. Species are listed in descending order of numerical importance; counts include both flying birds and birds on the water.

Common name	Scientific name	Total count	Percentage of total
Common murre	*Uria aalge*	6210	46.50
Unidentified dark shearwater	*Puffinus spp.*	2063	15.45
Sooty shearwater	*Puffinus griseus*	1522	11.40
Rhinoceros auklet	*Cerorhinca monocerata*	940	7.04
Black-legged kittiwake	*Rissa tridactyla*	769	5.76
Cassin's auklet	*Ptychoramphus aleuticus*	418	3.13
Northern fulmar	*Fulmarus glacialis*	200	1.50
Glaucous-winged gull	*Larus glaucescens*	164	1.23
Western x Glaucous-winged gull	*Larus occidentalis x glaucescens*	149	1.12
Herring gull	*Larus argentatus*	126	0.94
Western gull	*Larus occidentalis*	118	0.88
Ancient murrelet	*Synthliboramphus antiquus*	116	0.87
Surf scoter	*Melanitta perspicillata*	93	0.70
Black-footed albatross	*Phoebastria nigripes*	75	0.56
Pacific loon	*Gavia pacifica*	56	0.42
Unidentified gull	*Larus spp.*	51	0.38
Parakeet auklet	*Cyclorrhynchus psittacula*	48	0.36
California gull	*Larus californicus*	41	0.31
Mew gull	*Larus canus*	40	0.30
Northern pintail	*Anas acuta*	17	0.13
Marbled murrelet	*Brachyramphus marmoratus*	17	0.13
Pigeon guillemot	*Cepphus columba*	11	0.08
White-winged scoter	*Melanitta fusca*	11	0.08
Fork-tailed storm-petrel	*Oceanodroma furcata*	9	0.07
Red-throated loon	*Gavia stellata*	8	0.06
Pelagic cormorant	*Phalacrocorax pelagicus*	8	0.06
Brandt's cormorant	*Phalacrocorax penicillatus*	8	0.06
Bonaparte's gull	*Larus philadelphia*	7	0.05
Unidentified immature gull	*Larus spp.*	6	0.04
Mottled petrel	*Pterodroma inexpectata*	6	0.04
Pomarine jaeger	*Stercorarius pomarinus*	6	0.04
Leach's storm-petrel	*Oceanodroma leucorhoa*	5	0.04
Manx shearwater	*Puffinus puffinus*	5	0.04
Western grebe	*Aechmophorus occidentalis*	4	0.03

Table 6.(con't). Seabird species observed during marine bird survey effort. Species are listed in descending order of numerical importance; counts include both flying birds and birds on the water

Common name	**Scientific name**	**Total count**	**Percentage of total**
Brant	*Branta bernicla*	4	0.03
Common loon	*Gavia immer*	4	0.03
Black scoter	*Melanitta nigra*	4	0.03
Unidentified cormorant	*Phalacrocorax spp.*	4	0.03
Tufted puffin	*Fratercula cirrhata*	3	0.02
Short-tailed shearwater	*Puffinus tenuirostris*	3	0.02
Unidentified loon	*Gavia spp.*	2	0.01
Red-breasted merganser	*Mergus serrator*	2	0.01
Unidentified scoter	*Melanitta spp.*	1	0.01
Thick-billed murre	*Uria lomvia*	1	0.01
Total		**13355**	**100.00**

Table 7. Acoustic detections of marine mammals

Date	Detection #	Start Time	Start Lat	Start Long	Species
25-Mar-09	1	8:13	47.5794	-124.598	Unid Delph
26-Mar-09	2	3:20	46.8533	-124.59	O. Orca
27-Mar-09	3	7:15	46.8424	-124.691	O. Orca
27-Mar-09	4	7:57	45.5926	-124.101	O. Orca
27-Mar-09	5	17:15	46.4392	-124.297	O. Orca
28-Mar-09	6	6:39	47.1465	-124.582	O. Orca
30-Mar-09	7	6:43	48.4005	-125.506	O. Orca
1-Apr-09	8	13:59	48.2425	-123.929	O. Orca
2-Apr-09	9	3:53	48.4717	-124.401	O. Orca
4-Apr-09	10	16:18	46.1639	-124.413	O. Orca
6-Apr-09	11	4:12	45.8335	-124.454	O. Orca

Table 8. Killer whale encounters.

Date	Duration of encounter	Latitude	Longitude	Ecotype	Whales Present	
26-Mar	9hr, 11 min	47.01167	-124.5127	Resident	L pod	2 prey samples collected L12 biopsy sample collected
27-Mar	16hr, 42 min	46.263	-124.2283	Resident	L pod	
28-Mar	6hr, 10 min	47.23717	-124.5658	Transient		
29-Mar	3hr, 50 min	48.26117	-123.4218	Transient		
31-Mar	***	47.53267	-125.0472	Transient		***too rough to turn on
4-Apr	1hr, 31 min	47.9175	-125.001	Transient		
5-Apr	3hr, 52 min	46.24367	-124.3995	Transient		
6-Apr	3hr, 33 min	45.8085	-124.5577	Transient		Satellite tags deployed on T11 and T157 biopsy sample collected
8-Apr	1hr, 55 min	47.42567	-124.676	Transient		Satellite tag deployed on T173 and biopsy sample collected

Table 9. Summary of environmental data.

Sample type	Cruise total
Daily surface chlorophyll samples	84
Daily XBT drops	34
CTD casts	6
CTD chlorophyll samples	58
CTD nutrient samples	62
CTD salinity samples	25
Bongo net casts	55
Bongo net tow associated surface chlorophyll samples	48
Bongo net tow associated surface nutrient samples	36

Table 10. XBT deployment locations.

XBT #	Serial #	Max depth (m)	Sea surface temp (°C)	PST Date	PST time	Latitude (N)	Longitude (W)
1	1005918	150	9.6	3/24/09	9:37	48.2592	-125.2376
2	1005917	730	10.0	3/24/09	12:02	48.0068	-125.6715
3	1005913	134	10.1	3/24/09	15:00	48.0563	-125.0920
4	1005922	103	10.3	3/25/09	9:00	47.4923	-124.7445
5	1005921	342	10.6	3/25/09	15:00	47.1064	-124.9672
6	1005878	83	10.7	3/26/09	9:20	46.9942	-124.5290
7	1005879	107	9.5	3/27/09	9:05	45.6852	-124.1612
8	1005883	117	9.5	3/27/09	12:10	46.0262	-124.2925
9	1005881	78	8.7	3/28/09	15:00	47.6775	-124.7750
10	1005882	64	8.7	3/28/09	18:10	48.0933	-124.8948
11	1005886	191	7.6	3/29/09	9:11	48.2803	-124.0542
12	1005885	145	8.6	3/30/09	9:10	48.3727	-125.5767
13	1005881	260	8.2	3/30/09	12:10	48.2698	-125.8068
14	1005884	181	8.2	3/30/09	15:20	48.3703	-125.1988
15	1005877	256	8.2	3/31/09	9:00	47.7902	-125.0887
16	1005888	122	8.2	3/31/09	12:00	47.7095	-124.9345
17	1005886	1000	7.4	3/31/09	15:00	47.4940	-125.0132
18	1030364	1300	8.5	3/31/09	18:00	47.0512	-124.6618
19	1030363	173	7.7	4/1/09	9:10	48.4500	-124.7320
20	1030362	205	8.0	4/4/09	9:00	48.3577	-125.0428
21	1030358	178	8.3	4/4/09	12:05	48.0617	-125.5763
22	1030359	150	8.6	4/4/09	15:05	48.0437	-125.1978
23	1030360	101	8.4	4/5/09	9:20	46.8717	-124.5623
24	1030361	280	8.8	4/5/09	12:05	46.5713	-124.6250
25	1030357	90	9.1	4/5/09	15:07	46.3082	-124.2723
26	1030356	151	9.5	4/6/09	12:10	45.8535	-124.3582
27	1030355	145	10.4	4/6/09	15:10	45.4542	-124.2177
28	1030354	116	9.4	4/7/09	12:27	44.8255	-124.2535
29	1030374	115	9.3	4/7/09	15:15	45.1805	-124.1525
30	1030375	104	9.1	4/7/09	18:00	45.5458	-124.1490
31	1030377	80	8.3	4/8/09	9:29	47.2652	-124.6103
32	1036370	104	8.4	4/8/09	12:40	47.3077	-124.6733
33	1030371	95	8.7	4/8/09	15:00	47.6465	-124.8007
34	1030372	77	8.5	4/8/09	18:05	48.1088	-124.9148

Table 11. CTD deployment locations.

CTD #	Number of depths sampled	Max depth (m)	Local Date PST	Local Start Time PST	Lat (decimal degrees)	Long (decimal degrees)
1	12	1000	3/24/09	20:30	47.8002	-125.5583
2	11	500	3/25/09	20:43	46.9157	-124.8547
3	12	1000	3/30/09	21:11	48.0203	-125.7356
4	12	750	4/4/09	21:46	47.7469	-125.2642
5	9	150	4/5/09	21:06	46.1285	-124.6444
6	11	430	4/6/09	21:25	44.6522	-124.8845

Table 12. Bongo net cast locations.

Bongo Net	Sample Code	Date (local)	Latitude	Longitude	Start time (local)	Water Sample source	Chl samples collected	Nutrient samples collected
1	032509Cast01	03/25/09	47.7995	-125.5598	20:32	CTD	YES	YES
2	032509Cast02	03/25/09	47.82117	-125.0918	0:29	Surface	YES	YES
3	032509Cast03	03/25/09	47.82917	-124.8912	1:46	Surface	YES	YES
4	032509Cast04	03/25/09	46.91583	-124.8553	20:40	CTD	YES	YES
5	032509Cast05	03/25/09	46.9115	-124.8437	22:35	Surface	YES	YES
6	032509Cast06	03/25/09	46.91883	-124.7843	23:32	Surface	YES	YES
7	032609Cast07	03/26/09	46.41533	-124.3782	21:26	Surface	YES	YES
8	032609Cast08	03/26/09	46.31167	-124.3905	23:50	Surface	YES	YES
9	032709Cast09	03/27/09	46.2775	-124.3835	1:20	Surface	YES	YES
10	032709Cast10	03/27/09	46.24183	-124.383	2:30	Surface	YES	YES
11	032709Cast11	03/27/09	48.42667	-125.442	6:00	Surface	YES	NO
12	033009Cast12	03/30/09	48.02333	-125.743	20:40	CTD	YES	YES
13	033009Cast13	03/30/09	48.025	-125.6242	23:10	Surface	YES	NO
14	033109Cast14	03/31/09	48.04467	-125.4768	0:30	Surface	YES	NO
15	033109Cast15	03/31/09	48.02967	-125.3463	1:25	Surface	YES	YES
16	033109Cast16	03/31/09	48.0525	-125.2013	2:30	Surface	YES	YES
17	040109Cast17	04/01/09	48.27283	-123.5757	22:15	Surface	YES	YES
18	040109Cast18	04/01/09	48.2865	-123.6985	23:15	Surface	YES	NO
19	040209Cast19	04/02/09	48.30333	-123.8205	0:02	Surface	YES	NO
20	040209Cast20	04/02/09	48.32367	-123.9458	0:50	Surface	YES	YES
21	040209Cast21	04/02/09	48.35417	-123.0637	1:40	Surface	YES	NO
22	040209Cast22	04/02/09	48.3895	-124.1913	2:30	Surface	YES	NO
23	040209Cast23	04/02/09	48.41983	-124.3005	3:15	Surface	YES	YES
24	040209Cast24	04/02/09	48.47783	-124.4107	4:00	Surface	YES	NO
25	040209Cast25	04/02/09	48.3775	-124.4797	5:15	Surface	YES	NO
26	040209Cast26	04/02/09	48.33817	-124.3597	6:07	Surface	NO	YES
27	040309Cast27	04/03/09	48.19217	-123.5665	21:30	Surface	YES	YES

Table 12. Bongo net cast locations, cont.

Bongo Net	Sample Code	Date (local)	Latitude	Longitude	Start time (local)	Water Sample source	Chl samples collected	Nutrient samples collected
28	040309Cast28	04/03/09	48.192	-123.6997	23:10	Surface	YES	NO
29	040409Cast29	04/04/09	48.1905	-123.8328	1:00	Surface	YES	NO
30	040409Cast30	04/04/09	48.19717	-123.9498	2:00	Surface	YES	YES
31	040409Cast31	04/04/09	48.243	-124.0847	3:30	Surface	YES	NO
32	040409Cast32	04/04/09	48.28316	-124.2021	4:50	Surface	YES	NO
33	040409Cast33	04/04/09	48.3255	-124.359	5:50	Surface	YES	YES
34	040409Cast34	04/04/09	47.74692	-125.2642	21:46	CTD	YES	YES
35	040409Cast35	04/04/09	47.71867	-125.1017	23:40	Surface	YES	YES
36	040509Cast36	04/05/09	47.66383	-125.0293	0:35	Surface	YES	YES
37	040509Cast37	04/05/09	47.61708	-125.8822	1:56	Surface	YES	YES
38	040509Cast38	04/05/09	47.55467	-124.7423	3:03	Surface	YES	YES
39	040509Cast39	04/05/09	46.12845	-124.6444	21:06	CTD	YES	YES
40	040509Cast40	04/05/09	46.09083	-124.5355	22:40	Surface	YES	YES
41	040609Cast41	04/06/09	46.03892	-124.3227	0:10	Surface	YES	YES
42	040609Cast42	04/06/09	45.99883	-124.238	1:00	Surface	YES	YES
43	040609Cast43	04/06/09	45.94433	-124.0762	2:10	Surface	YES	YES
44	040609NH35	04/06/09	44.65218	-124.6461	21:25	CTD	YES	YES
45	040609NH25	04/06/09	44.65435	-124.6461	23:40	Surface	YES	YES
46	040709Cast46	04/07/09	44.1255	-124.8953	3:20	Surface	YES	YES
47	040709Cast47	04/07/09	44.099	-124.8147	4:15	Surface	YES	YES
48	040709NH05	04/07/09	44.64817	-124.1805	10:05	Surface	YES	YES
49	040709Cast49	04/07/09	46.23034	-124.2897	22:35	Surface	YES	YES
50	040709Cast50	04/07/09	46.2715	-124.3473	23:20	Surface	YES	YES
51	040809Cast51	04/08/09	46.3508	-124.3472	0:20	Surface	YES	YES
52	040809Cast52	04/08/09	46.43983	-124.394	1:25	Surface	YES	YES
53	040809Cast53	04/08/09	46.5215	-124.5057	3:00	Surface	YES	YES
54	040809Cast54	04/08/09	46.549	-124.5102	3:50	Surface	YES	YES
55	040809Cast55	04/08/09	46.597	-124.4328	4:50	Surface	YES	YES

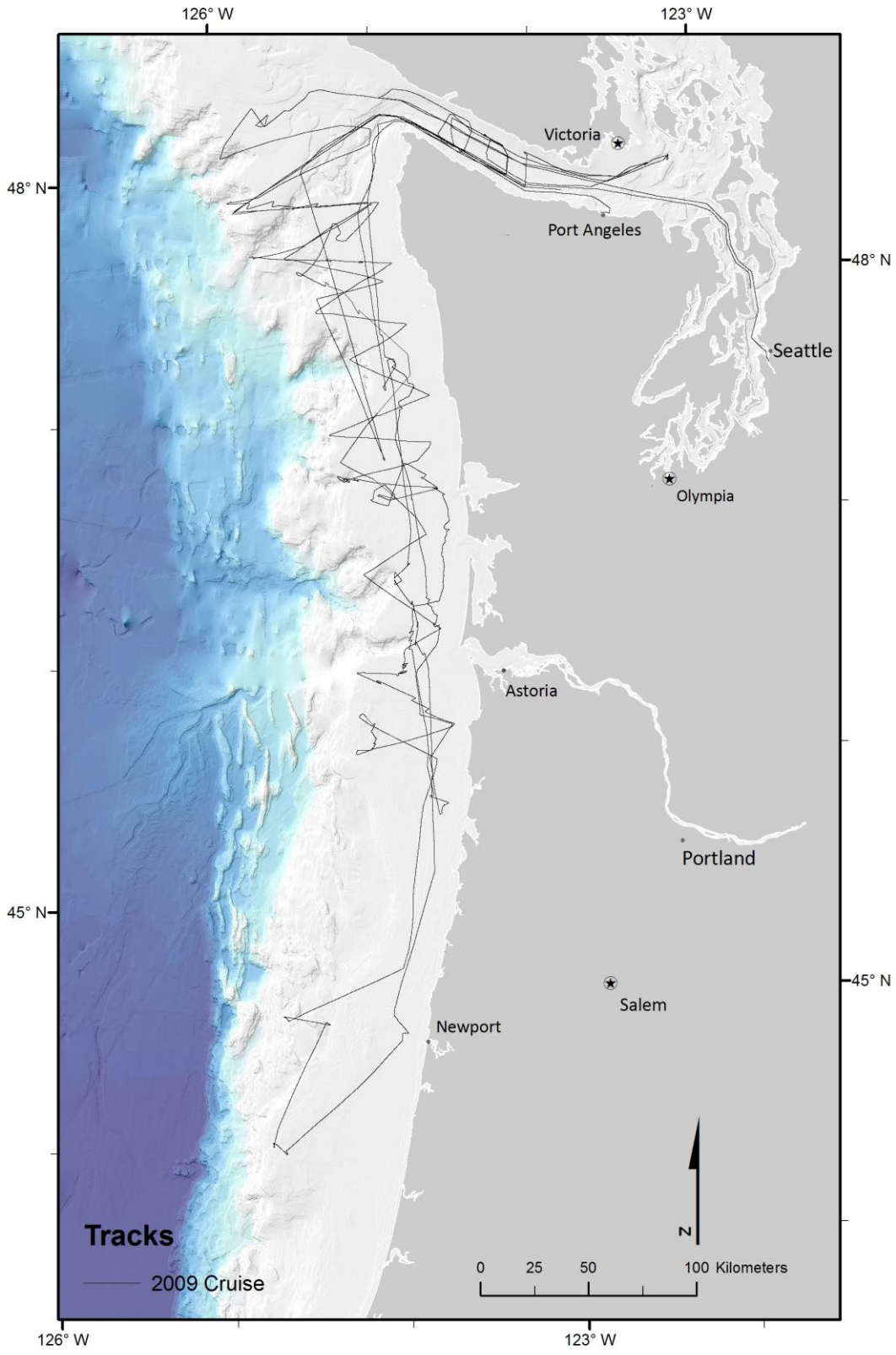

Figure 1. Cruise track of the McArthur II from 23 March – 9 April 2009.

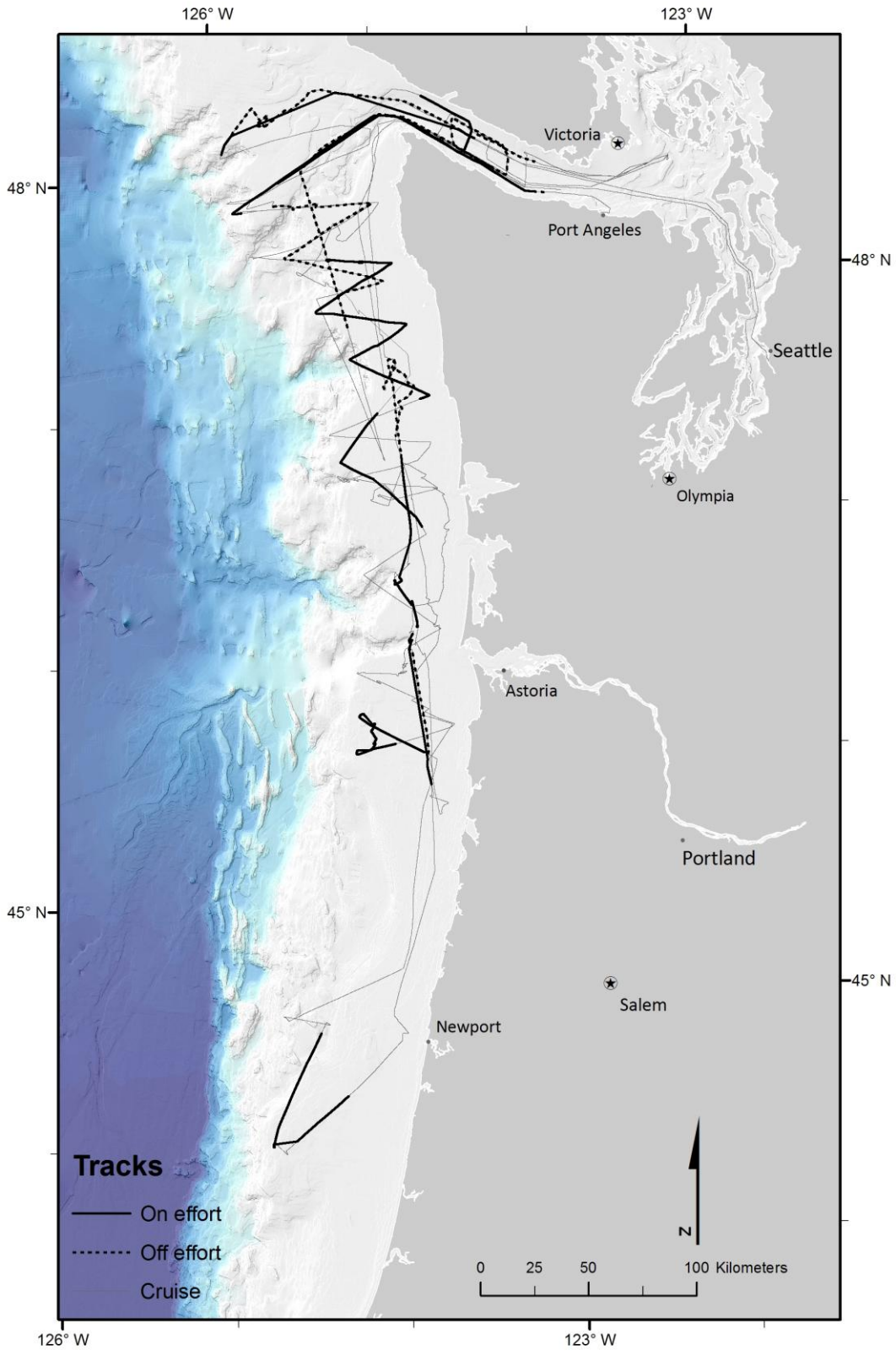

Figure 2. Visual On and Off – effort monitoring of marine mammals from 23 March – 9 April 2009.

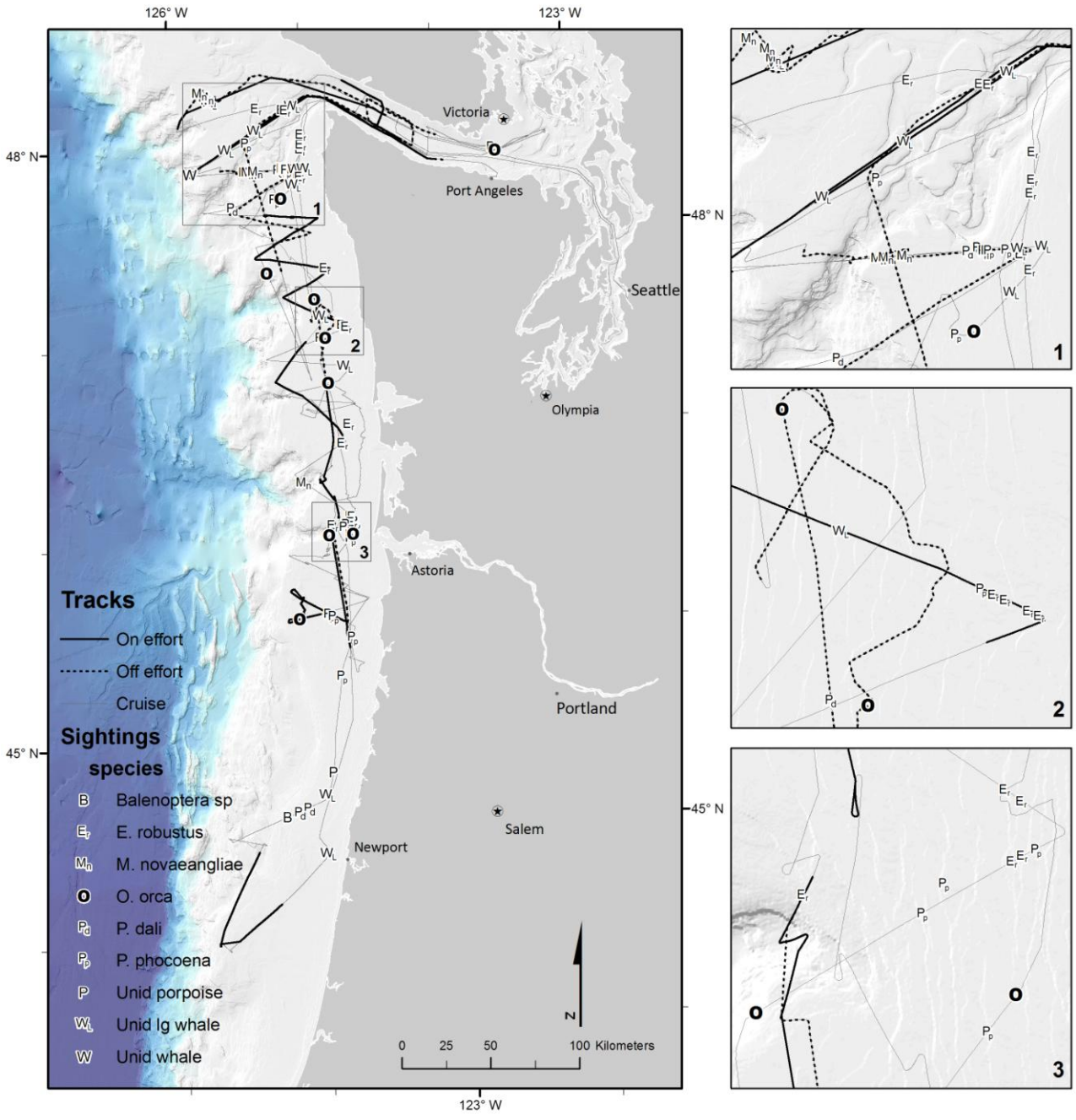

Figure 3. On and Off-effort sightings of marine mammals from 23 March – 9 April 2009.

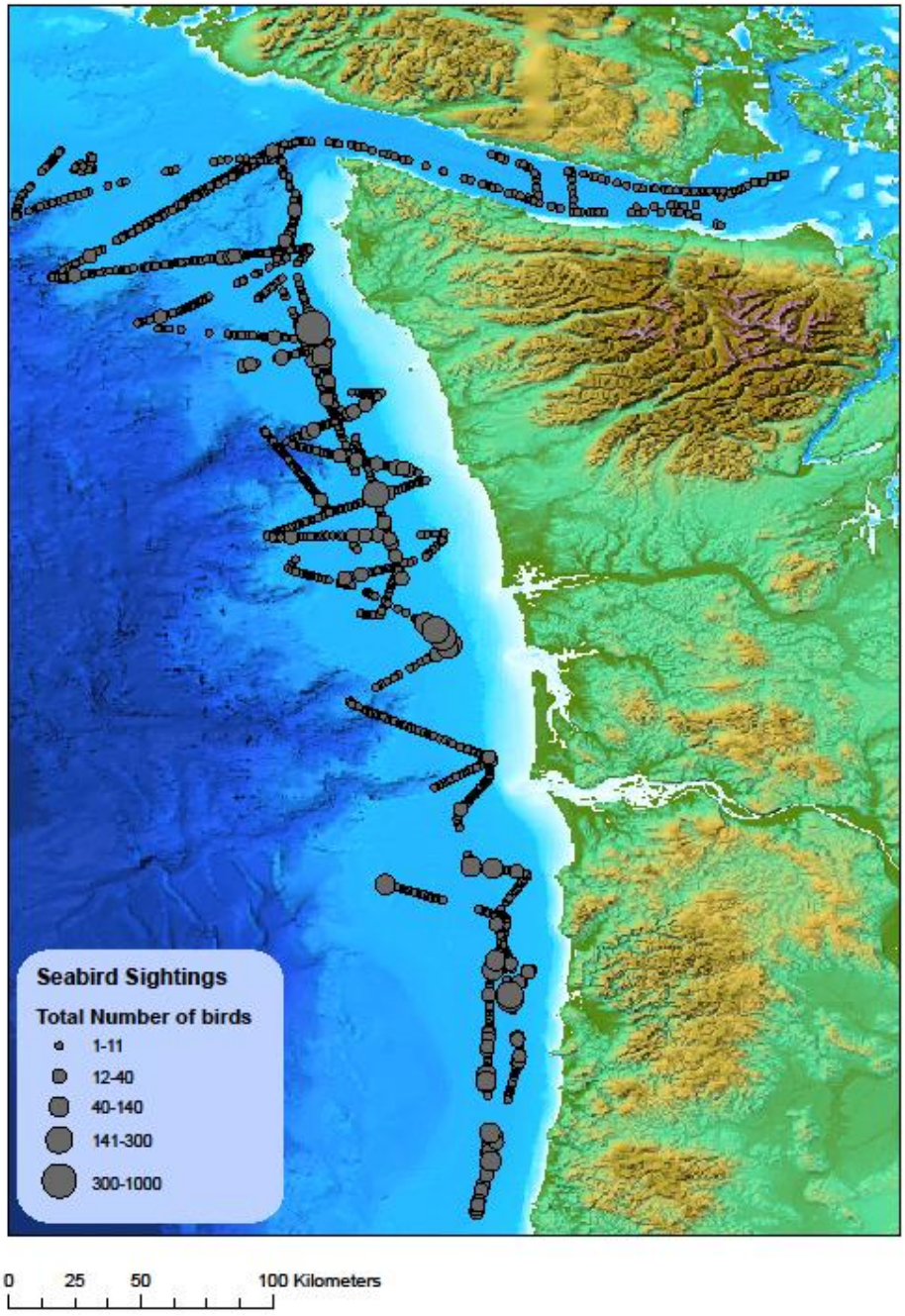

Figure 4. Sightings of seabirds from 23 March – 9 April 2009

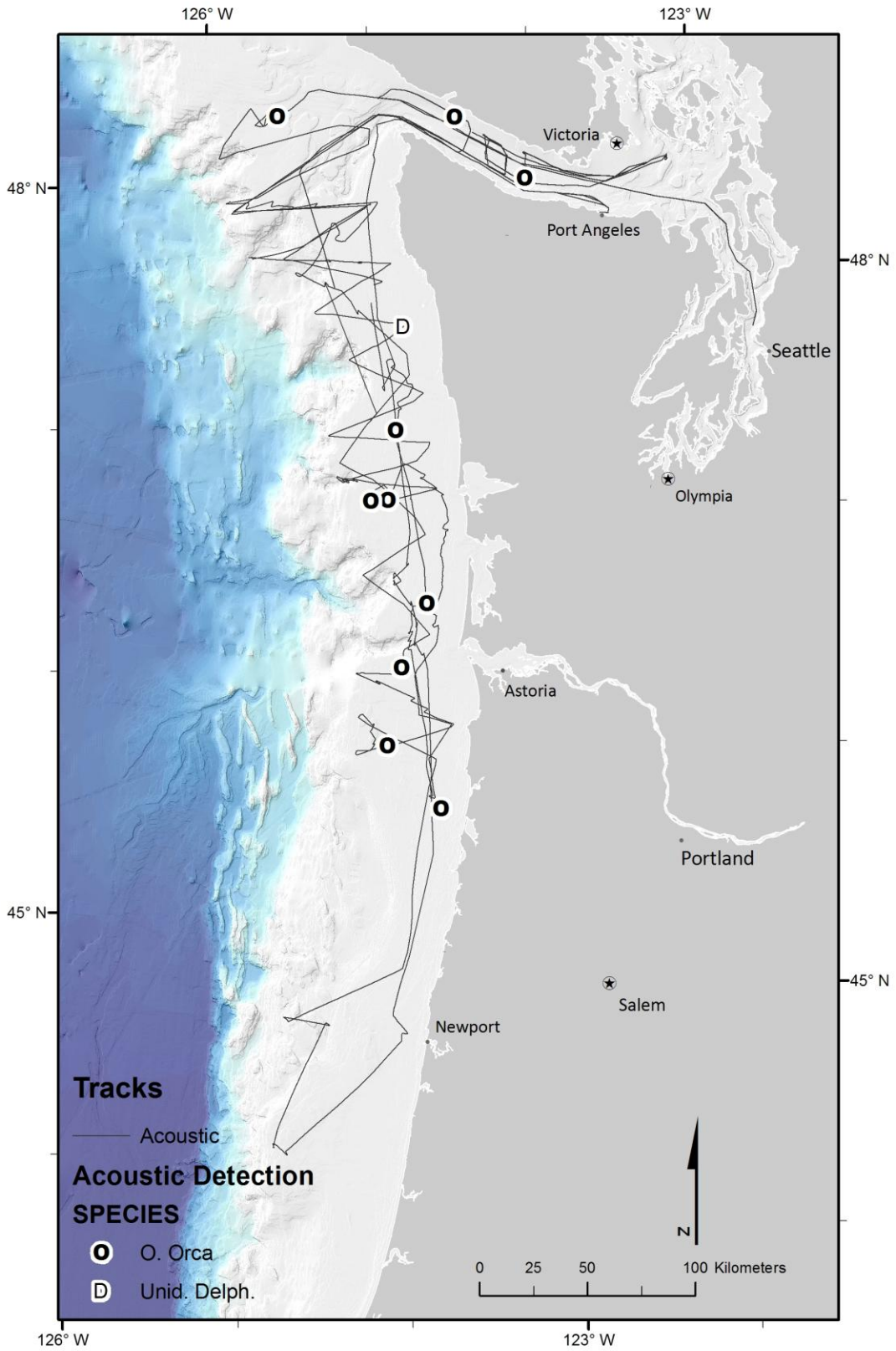

Figure 5. Acoustic detections of marine mammals from 23 March – 9 April 2009.

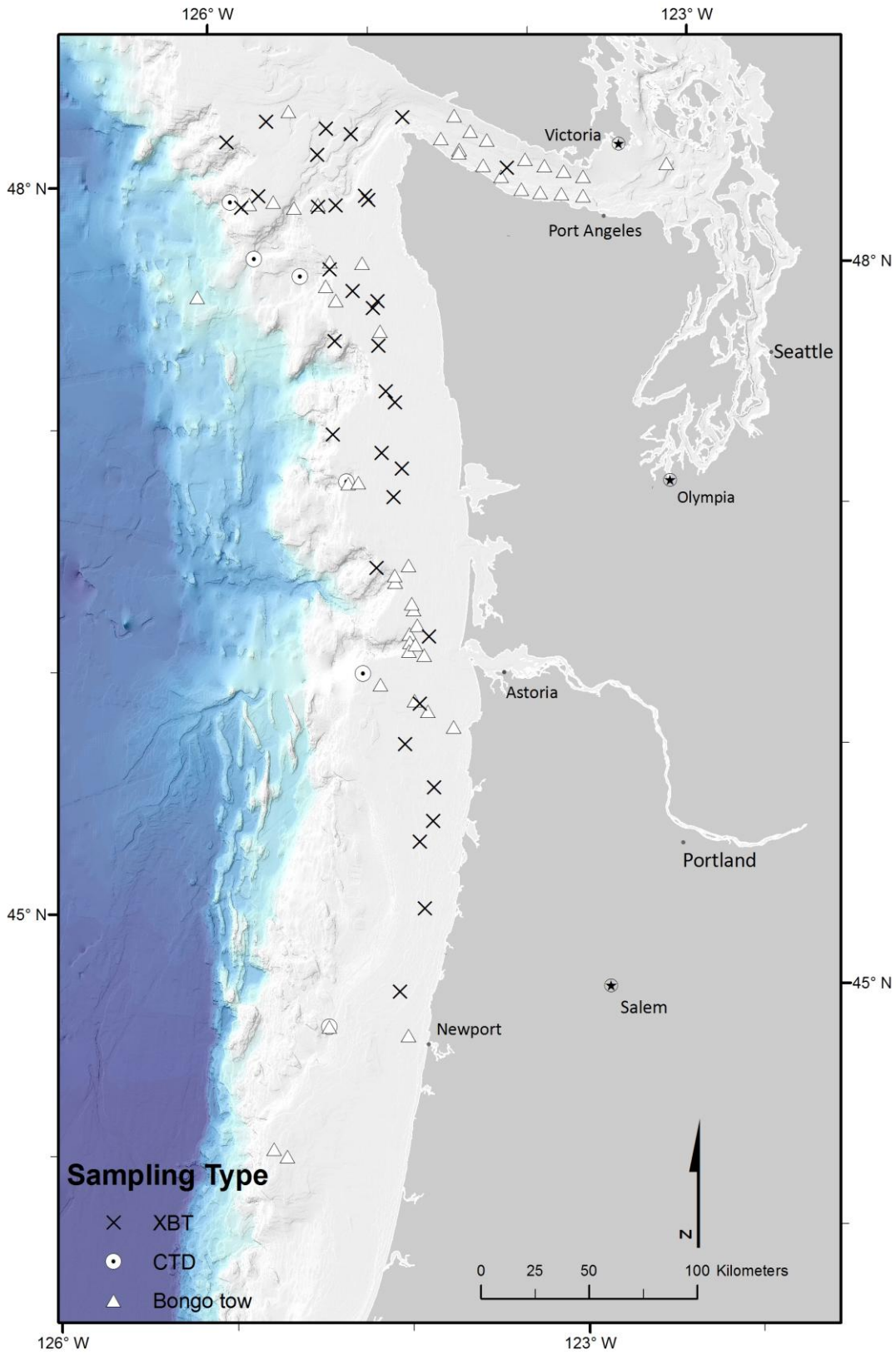

Figure 6. XBT and CTD deployments from 23 March – 9 April 2009.